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(11) Publication number:

0 186 585

A2

(12)

## EUROPEAN PATENT APPLICATION

(21) Application number: 85402542.6

(51) Int. Cl.: H 01 L 23/48

(22) Date of filing: 18.12.85

(30) Priority: 19.12.84 US 683995

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(40) Date of publication of application:  
02.07.86 Bulletin 86/27

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(44) Designated Contracting States:  
DE FR GB IT NL

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(54) Die bonding process.

(57) A process for bonding a silicon die to a package. This process comprises the following steps: (a) providing to the back surface of the die a barrier layer which is impervious to silicon; (b) providing to the barrier layer a layer of gold; and (c) bonding the die to the package by activating a binder composition disposed at the interface of the package and the layer of gold. The barrier layer prevents the migration of silicon to the gold layer, both at the time of application of the gold layer to the die and at the time of bonding the die to the package. Titanium and tungsten are preferred barrier layer materials, while the preferred binder composition is a gold-tin alloy solder. The prevention of silicon migration into the gold produces highly reliable bonds.

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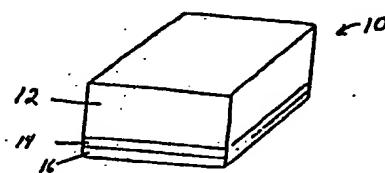


Fig. 1

DIE BONDING PROCESS

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Background of the Invention

The present invention relates generally to processes for fabricating semiconductor intergrated circuit devices and more particularly to a process for bonding a semiconductor die to its package.

In order to facilitate handling and the making of electrical connections thereto, it is necessary to securely place the intergrated circuit device, or die, in a package. Electrical connections are thereafter made from predetermined points on the device to contacting pins on the package. Since the electrical connections from the device to the contacting pins are necessarily very fine they are also very fragile; and, unless the die is securely and permanently fastened to the package, mechanical shock or vibration may separate the die from the package causing one or more of the electrical contacts to break which in turn causes failure of the intergrated circuit device.

A typical method of bonding the die to the package is to place a preform of gold-tin solder in a recess in the package, which recess is diminished to receive the die. The back surface of the die is coated with a layer of gold to which the preform adheres after melting.

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It has been found that the above described bonding process can result in unsatisfactory bonds due to the migration of silicon from the die into its gold layer. Such migration occurs during the process of 5 coating the gold on the back surface of the die and alloying the gold thereon. Specifically, the gold is deposited on this back surface and the resultant combination is heated in order to alloy the gold onto the silicon die. This process requires a high 10 temperature, generally about 400°C, which causes silicon migration into the gold. Further, the eutectic process of adhering the die to the package also requires a similar high temperature which, in turn, causes additional silicon migration to the bonding site. This 15 resultant silicon adulteration of the gold and the gold-tin preform acts to inhibit formation of a reliable bond between the die and the package.

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Summary of the Invention

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Accordingly, it is a general object of the present invention to provide a method for establishing a reliable bond between a semiconductor die and its package.

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This and other objects of the invention are attained, in accordance with one aspect of the invention by a process for bonding a silicon die to a package, said process comprising the steps of: a) forming a barrier layer of a refractory metal material onto a back surface of said silicon die; b) forming a layer of bonding material over said barrier layer; and c) bonding the die to the package by activating a binder composition disposed at the interface of the package and 35 said bonding metal layer.

Another aspect of the invention includes a semiconductor device including a bonding metal layer disposed on a back surface of a silicon die for bonding said die to a package, characterized by a barrier layer of a refractory metal material interposed between said bonding layer and the back surface of said silicon die.

5 Other objects, features and advantages of the present invention will become more fully apparent from the following detailed description of the preferred embodiment, the appendent claims and the accompanying drawings.

15 Brief Description of the Drawings

Fig. 1 is a perspective view of a die having a barrier layer and a gold layer.

Fig. 2 is a perspective view of a second embodiment of a die; and

20 Fig. 3 is a top perspective view of a package to which the die can be bonded.

25 Detailed Description of a Preferred Embodiment

Referring to Fig. 1, a die generally referred to as 10, comprises a silicon substrate 12 having a barrier layer 14 formed over a back surface thereof. A bonding layer 16 is formed over the barrier layer 14. The barrier layer 14 comprises a refractory metal, selected from the group consisting essentially of titanium, tungsten, tantalum and niobium. The bonding layer 16 comprises a precious or noble metal, preferably gold or silver. The barrier 14 and bonding 16 layers are preferably formed as follows.

The back surface of a silicon wafer is lapped, ground or etched to obtain a substantially flat, smooth, oxide-free surface. The surface is then back sputtered to assure cleanliness before any metal is applied.

5       The barrier layer 14 of the refractory metal is then formed to a predetermined thickness on the back surface of the wafer utilizing a known technique such as sputtering. In a preferred embodiment, titanium is sputtered onto the back surface of the wafer to form the  
10      barrier layer 14 having a thickness preferably equal to about 500 $\text{\AA}$ . The bonding layer 16 of the precious or noble metal is then formed over the barrier layer 14 to a predetermined thickness utilizing a known technique such as sputtering. In a preferred embodiment, gold is sputtered onto the barrier layer 14 to a thickness of  
15      about 1,000 $\text{\AA}$  to form the bonding layer 16. The back sputtering, titanium application, and gold application are done consecutively as a continuous operation.  
20      Optionally, and as shown in Fig. 2 the barrier layer can comprise a plurality of strata. Thus, the die 30 of Fig. 2 has a first stratum 32 of a refractory metal such as titanium and a second stratum 34 of a refractory metal such as tungsten. Preparation procedures for the die 30 are the same as outlined above for the die 10,  
25      except that the tungsten is sputtered onto the titanium prior to the sputtering of the gold.

Upon completion of the above steps, the wafer is diced and individual dies such as the one shown in Fig. 1 are produced. Bonding the die 10 to a package 18, as shown in Fig. 3, is preferably accomplished through employment of a solder preform 20. The solder preform 20 preferably is made of a precious metal eutectic such as gold-tin, gold-silicon, or gold-antimony. The bonding procedure involves, first of all, heating the package 18 to a predetermined  
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temperature, for example about 305°C when using a gold-tin solder preform. The solder preform 20 is then placed at the site of proposed bondings, for example in a recess 22 as shown in Fig. 3. When the preform 20 is melted, the die 10 is placed thereon and excess preform 20 is wrung from under the die 10. The resultant assembly is then cooled, and bonding of the die 10 to the package 18 is complete.

The purpose of the barrier layer is to prevent the migration of silicon to the gold layer, both at the time of application of the gold layer to the die and at the time of bonding the die to the package. Additionally, the presence of the barrier layer requires less gold to be used for the gold layer. In the prior art, because silicon migrated into the gold, a greater quantity of gold was required to endeavor to overcome dilution by the silicon. In the instant die, however, because silicon cannot migrate through the barrier layer, the gold layer does not experience such dilution. As a result, a compensatory amount for dilution need not be employed. Further, the presence of the barrier layer enables a better eutectic bonding which can be performed at a lower temperature because no silicon can migrate to a site within the bonding composition. Thus, bonding using a gold-tin alloy solder can be carried out at a temperature of about 305°C as opposed to a temperature of about 330°C, the standard processing temperature.

As previously stated, the barrier layer material preferably is a refractory metal such as tungsten, titanium, tantalum or niobium. However, palladium can also be employed, as can other materials which would be recognized by the skilled artisan. Optionally, the barrier layer can have a plurality of strata. It is important to consider the doping

characteristics when providing a metal barrier layer material. Thus, for example, a P-type semiconductor would use a P-type metal; an N-type semiconductor would use an N-type metal. It is preferred that the barrier layer be sputtered onto the back surface of the die, a process known in the art which involves the use of metal vapors which subsequently condense onto the die. Layers so applied can range in thickness from about 500 $\text{\AA}$  to about 10,000 $\text{\AA}$  (1 micron). The barrier layer also could be applied by an evaporator, also as known in the art. In some cases, the barrier layer must be able to conduct heat and current.

The preferred binder composition is a gold-tin alloy solder which is, of course, activated by heat. As earlier related, the solder process can be performed at a temperature below that utilized in standard processing.

As would be recognized by those having skill in the art, the process here disclosed provides many benefits. First of all, temperatures lower than those required for prior art bonding processes can be employed. Secondly, gold consumption is reduced since the amount of gold in the gold layer 16 can be reduced, as earlier described, due to prohibition of silicon migration. Thirdly, the reliability of the bond is enhanced, again due to prohibition of silicon migration. Finally, from an operational standpoint, the process is relatively simple to perform, thereby requiring no special skills on the part of an operator.

It will be understood that various changes in the details, materials and arrangement of the parts which have been herein described and illustrated in order to explain the nature of this invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the following claims.

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CLAIMS

What is claimed is:

1. A process for bonding a silicon die to a package, said process characterized by the steps of:
  - a) forming a barrier layer of a refractory metal material onto a back surface of said silicon die;
  - b) forming a layer of bonding material over said barrier layer; and
  - c) bonding the die to the package by activating a binder composition disposed at the interface of the package and said bonding metal layer.
2. The process according to claim 1 characterized in that the barrier layer is selected from the group consisting essentially of titanium, tungsten, tantalum and niobium.
3. The process according to claim 1 characterized in that the barrier layer comprises palladium.
4. The process according to claim 1, 2 or 3 characterized in that the barrier layer is sputtered onto the back surface of the die.
5. The process according to any one of claims 1-4 characterized in that the thickness of the barrier layer provided is from about 500 $\mu$  to about 10,000 $\mu$ .
6. The process according to any one of claims 1-5 characterized in that the barrier layer is thermally conductive.

7. The process according to any one of claims 1-6 characterized in that the barrier layer is electrically conductive.

8. The process according to any one of claims 1-7 characterized in that the barrier layer is comprised of a plurality of strata.

9. The process according to claim 8 characterized in that the barrier layer has one stratum of titanium and one stratum of tungsten.

10. The process according to any one of claims 1-9 characterized in that the binder composition comprises a precious metal eutectic.

11. The process according to claim 10 characterized in that the binder composition is selected from the group consisting essentially of gold-tin, gold-silicon and gold-antimony.

12. The process according to claim 11 characterized in that the bonding composition comprises a gold-tin alloy solder preform.

13. The process according to claim 12 characterized in that the binder composition is activated by a temperature of about 305°C.

14. The process according to any one of claims 1-13 characterized in that the bonding layer comprises a noble metal.

15. The process according to claim 14 characterized in that the bonding layer metal is selected from the group consisting essentially of gold and silver.

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16. A semiconductor device including a bonding metal layer disposed on a back surface of a silicon die for bonding said die to a package, characterized by a barrier layer of a refractory metal material interposed between said bonding layer and the back surface of said silicon die.

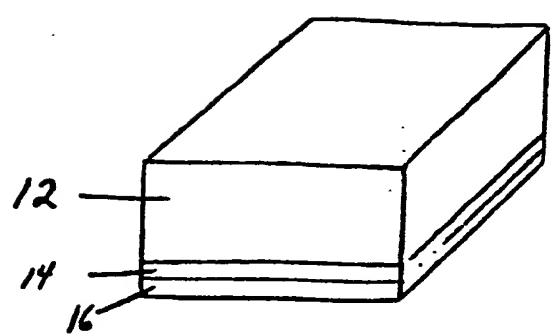
17. The apparatus according to claim 16 characterized in that the barrier layer material is chosen from the group consisting essentially of titanium, tungsten, tantalum and niobium.

18. The apparatus in accordance with claim 16 or 17 characterized in that said bonding material layer comprises a noble metal.

19. The apparatus according to claim 18 characterized in that said bonding metal layer comprises a noble metal selected from the group consisting essentially of gold and silver.

20. The apparatus according to claim 16, 17, 18 or 19 characterized in that said barrier layer comprises a plurality of strata.

21. The apparatus according to claim 20 characterized in that the barrier layer comprises one stratum of titanium and one stratum of tungsten.



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Fig. 1

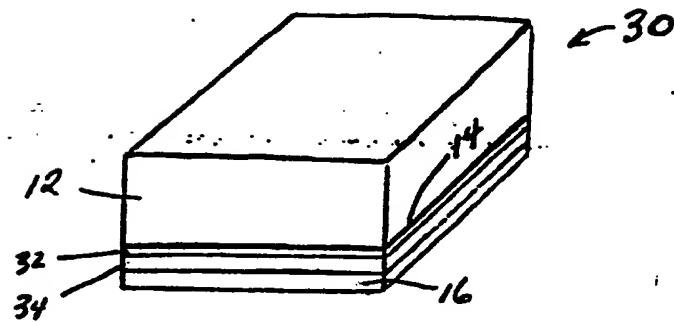


Fig. 2

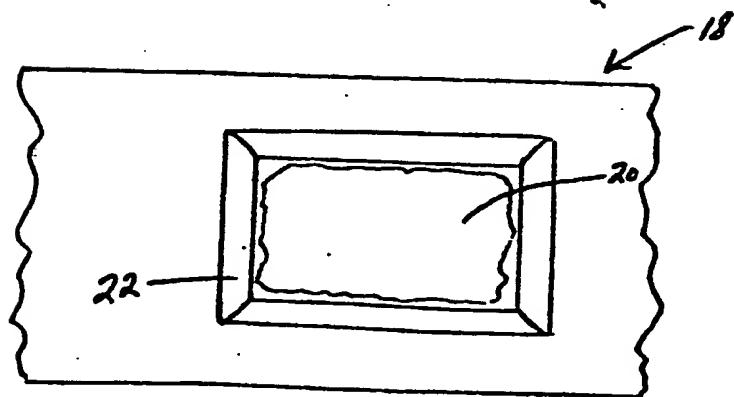


Fig. 3